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Potential for Conversion and Utilization of Solar Energy in Poultry Production

by

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Final Report

Covering the period from 1975 to 1980

Brooding Broiler Chickens with Solar Energy

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ABSTRACT

A research team was assembled to evaluate the potential for conversion and utilization of solar energy in broiler chicken production. An analysis of brooding energy needs and solar energy availability for all sections of the United States was conducted. Typical results of the analysis are presented. The results of the analysis were used to design a research facility which is described. The facility was used to evaluate several brooding systems. Brooding system performance and operational parameters are discussed. Brooding broiler chickens with solar energy was shown to be technically feasible although some practical problems with its implementation still exist.

INTRODUCTION

Chickens require an external source of heat during the first 2 to 4 weeks of life in order to maintain body temperature. Fossil fuels are the standard heat energy source for brooding chickens. LP gas is used for about 82 percent of the broilers produced in the United States (Brewer et al., 1978). In 1974, an average of 155 liters of LP gas was required for each 1000 broilers produced. While conservation efforts can reduce energy needs, heat requirements cannot be totally eliminated. As the fossil fuel supply becomes limited, alternative energy sources must be found. In addressing this problem, a long term interdisciplinary

program was begun to investigate the potential for conversion and utilization of solar energy in poultry production programs. The ultimate goal was to find ways to make solar energy a heat source acceptable to the industry.

PRELIMINARY ANALYSIS

A necessary first step in a study of solar energy utilization is an analysis of the energy requirements for the particular application. A feasibility study of the potential for conversion and utilization of solar energy in poultry production was conducted (Brewer and Dunn, 1975). The study consisted of a survey of brooding energy used by all kinds of poultry throughout the United States (Brewer et al., 1978), an analysis of energy used in brooding broiler chickens (Flood et al., 1979), an analysis of selected solar heating systems, and a economic analysis.

Design of a solar heating system which is both economically and functionally feasible depends not only on the total brooding energy required to grow birds to market age but also on the variation in these requirements throughout the year and on the daily requirements during a grow-out period. A computer simulation was used to develop brooding energy requirements as a function of bird age for production of broiler chickens (Flood et al., 1979).

Daily and half-day energy requirements were investigated for a typical building-type temperature-schedule combination for several sites in the United States. The day was divided into a warm period and a cool period centered upon noon and midnight. Since results for all sites had similar distributions with time, a typical Southeast United States example will be used to illustrate the findings.

Daily and half-day energy requirements for a typical site for birds grown during the first calendar quarter are shown in Figure 1. As can be seen, the heat required starts at approximately 525 megajoules per day (MJ/day) and drops rapidly to about 140 MJ/day when the birds are 4 weeks of age and levels out at about 90 MJ/day for the last 3 weeks of an 8-week grow-out period. The reason for the decrease in energy needs is a combination of lower house temperature requirements as the birds age and an increased sensible heat output by the birds.

Half-day heating requirements are initially distributed as 60 percent night and 40 percent day. Daytime requirements drop to about 6 percent of the daily total by the time birds are 5 weeks old.

Daily energy requirements for all four quarters are shown in Figure 2. Fourth quarter requirements are similar to those for the first quarter. First and fourth quarter results shown are probably the reverse of the long term average since the first quarter average temperature was about 2 C higher than normal and the fourth quarter average was about 2 C lower than normal. Second quarter requirements are initially about 300 megajoules per day and drop to zero by about 4 weeks while the third quarter starts at 150 MJ/day and drops to zero by the end of the third week. Thus, it is seen that a system sized to supply all of the heat requirements by solar energy during the first and fourth quarters would be grossly oversized during the second and third quarters.

The pattern of energy use throughout the year is illustrated by Figure 3. Typical total fuel required to brood birds for 8

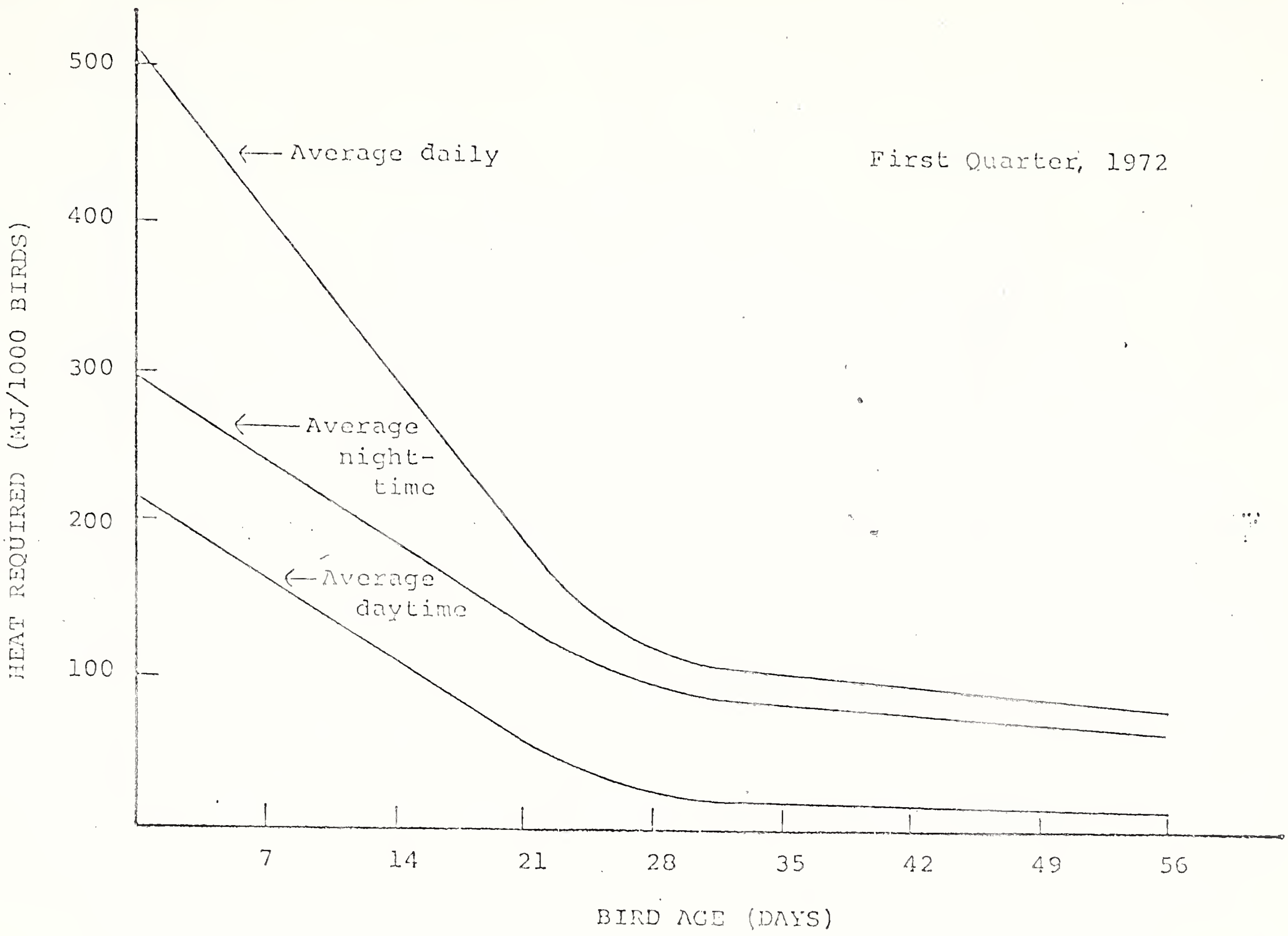

Fig. 1, Typical average daily and half-day heat requirement

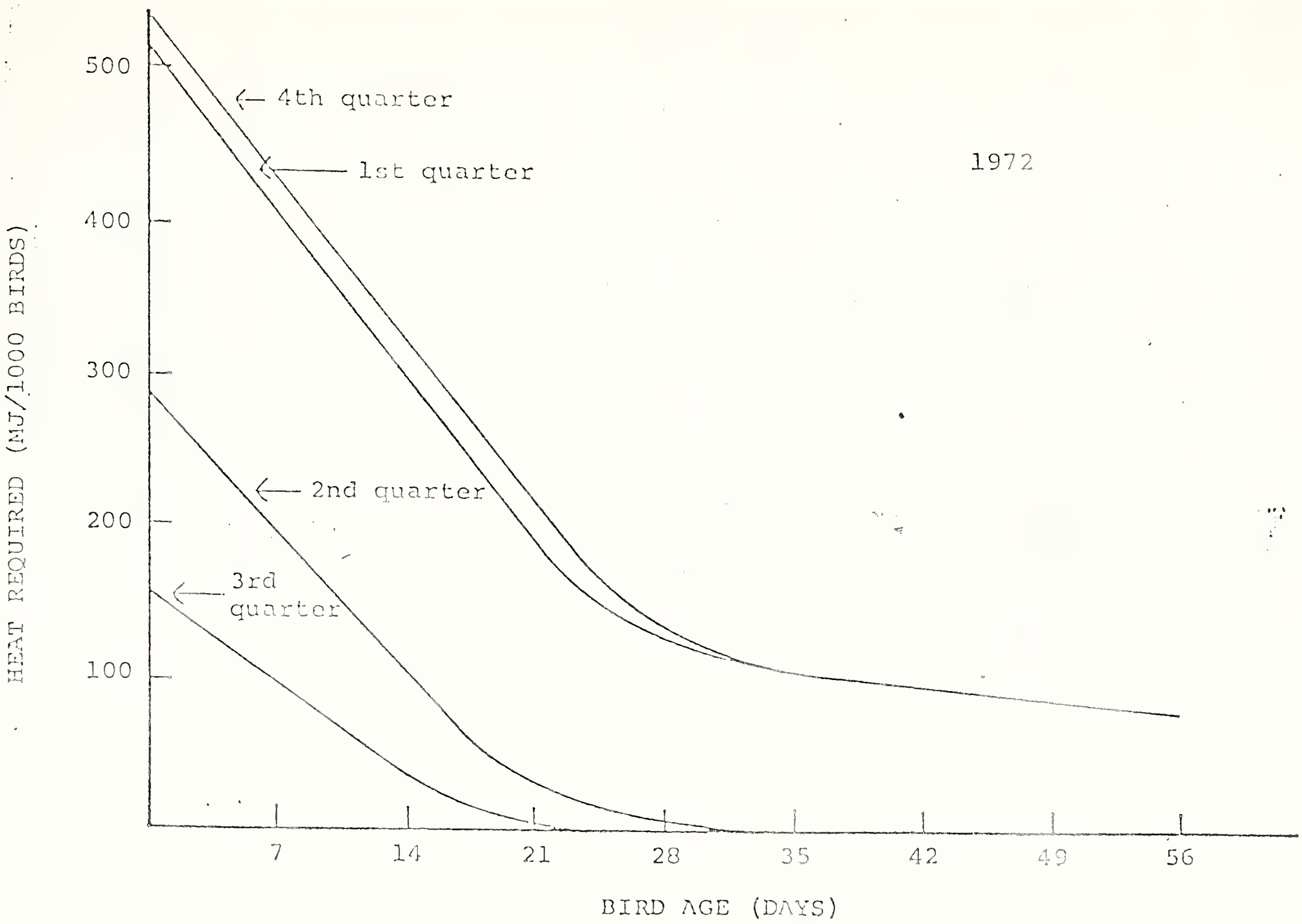

Fig. 2. Typical average daily heat requirements by quarter

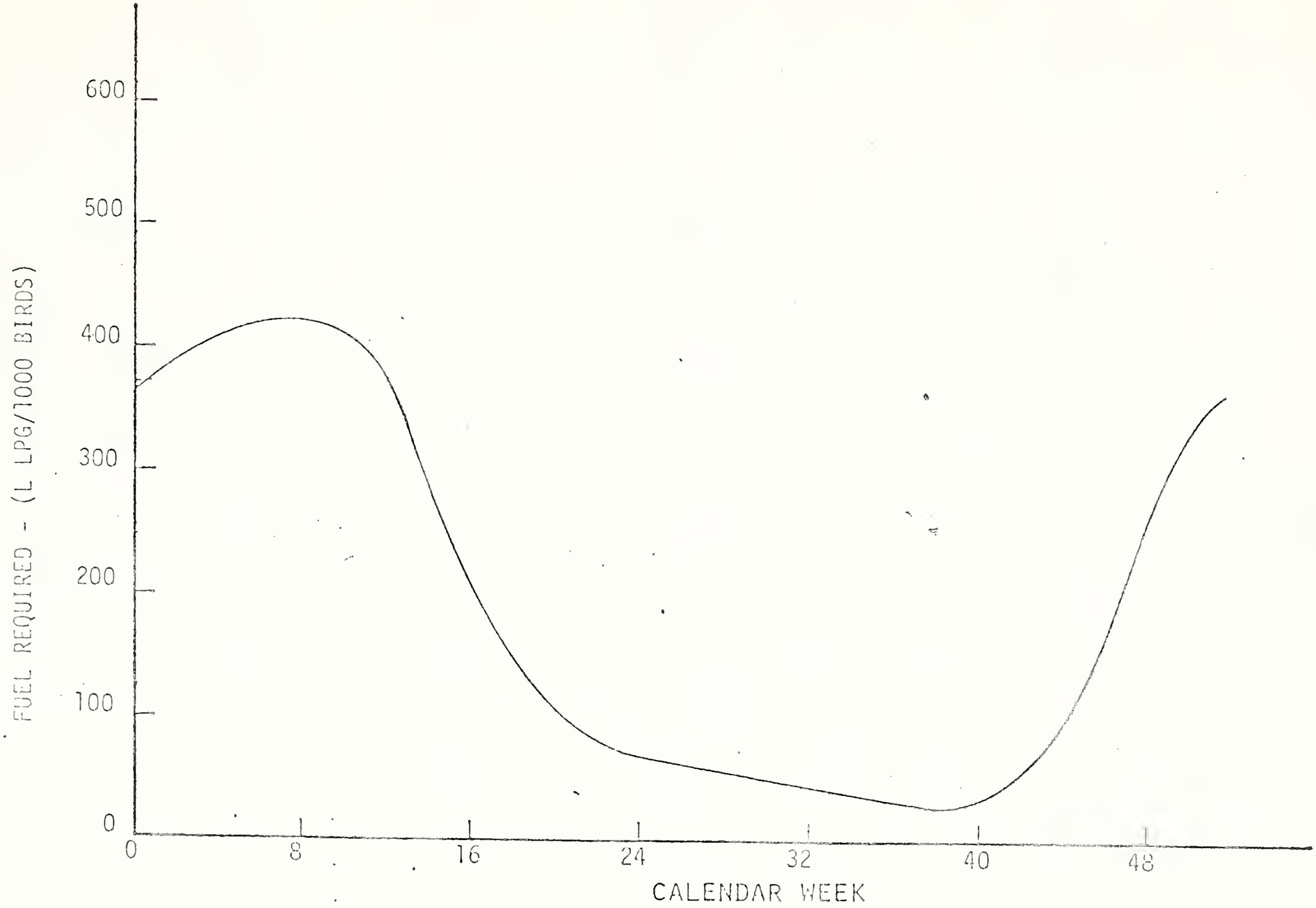

Fig. 3. Typical eight week fuel requirement

weeks with birds marketed at the end of each calendar week is shown. There is little change in the energy requirement during the quarter for birds marketed during the first and third quarters while requirements drop steadily during the second quarter and rise steadily during the fourth quarter. This pattern is typical of the results obtained for all cases studied.

These results provide the basic heat requirement data necessary for analysis and design of a solar heating system for brooding broiler chickens. Two major problem areas are apparent, both of which involve the time distribution of heat requirements. First, it is seen that first quarter total heat requirements are approximately 12 times as large as third quarter requirements (Figure 3). Second, daily energy requirements decrease rapdily during the first 4 weeks of the grow-out period. In fact, essentially no heat is required after 4 weeks during the second and third quarter (Figure 2). It will be very difficult to design solar heating systems which can be utilized efficiently when there are such pronounced differences in the magnitude of heat requirements with time. A goal of this research program has been to study heating system and broiler house design as well as poultry management in order to develop a solar heated broiler brooding system which can be effectively utilized all months of the year.

The performance of a typical water filled solar collector-storage system was analyzed for several sites in the United States. Results of our analysis for Cullman, Alabama will be used to illustrate the findings (Figure 4). Auxiliary energy requirements as a percentage of the total brooding energy required are shown

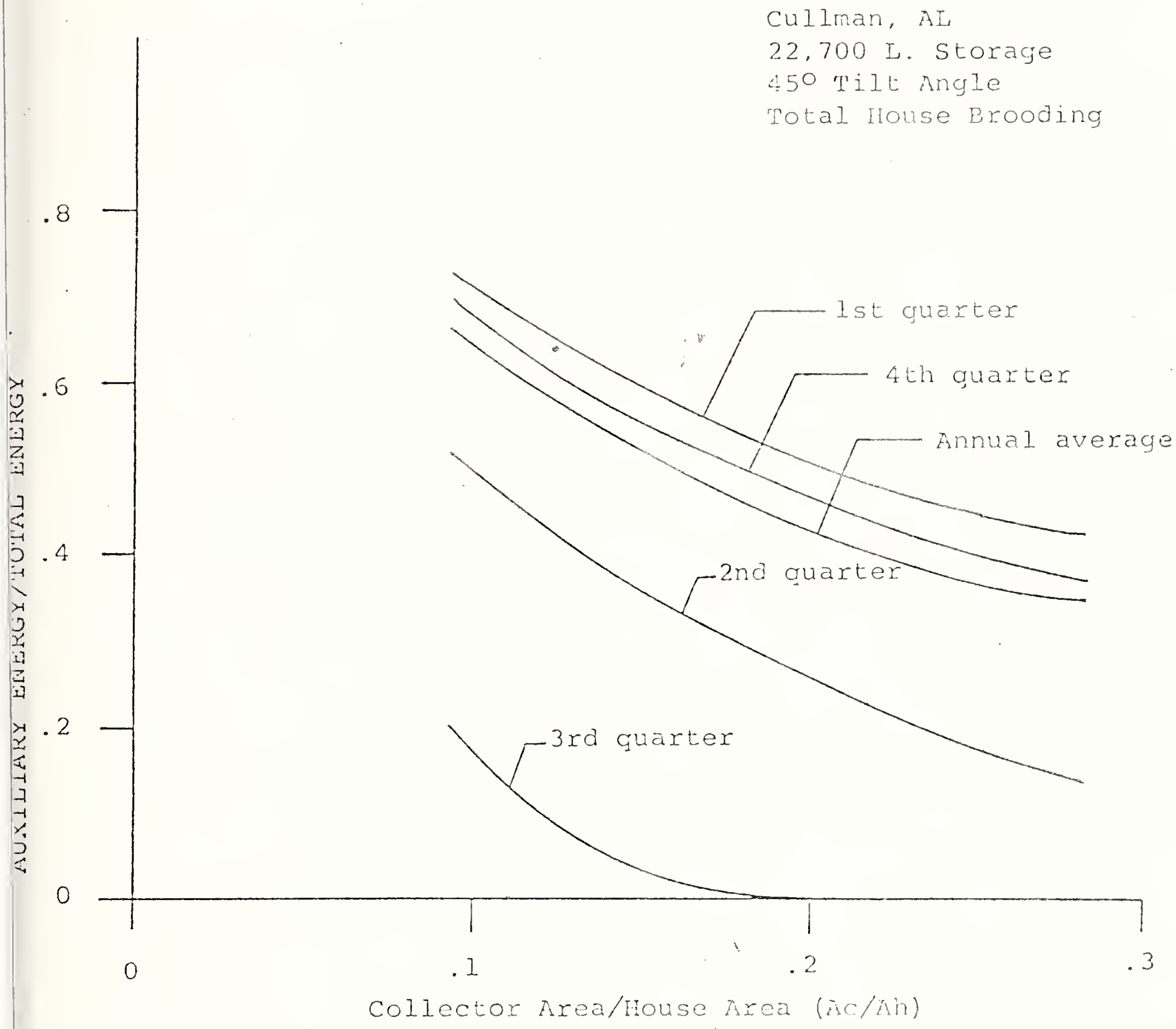

Fig. 4. Typical auxiliary energy requirements

as a function of the ratio of collector area to broiler house area (Ac/Ah). Calculations were made for birds grown during each of the four calendar quarters as well as an average calculation for the year.

A study of Figure 4 leads to several observations in regard to the application of solar energy to the brooding of broiler chickens in conventional production facilities under conventional management practices.

1) The rate of reduction in the percentage auxiliary energy required as Ac/Ah increase becomes very small as Ac/Ah becomes greater than 0.25. This is particularly true for the first and fourth quarters and the annual average.

2) Auxiliary energy requirements are likely to be at least 40 percent of the total brooding energy requirements during the first and fourth quarters for economical Ac/Ah ratios.

3) A system sized to supply 60 percent or more of the brooding energy needs during the first and fourth quarter will be greatly oversized for third quarter use and probably will be oversized for the latter portion of the second quarter.

The results shown in Figures 1 to 4 seem to indicate that brooding of broiler chickens may not be a practical or perhaps even an economical application of solar energy. It should be remembered; however, that these results were for conventional housing and conventional management practices. Research on housing design, brooding systems, and management practices may lead to changes which would increase efficiency of brooding energy use and decrease the magnitude of the variation of brooding energy requirements with time. Should research lead to the development of a

system for which both daily and quarterly variations in brooding energy requirements are small, solar energy may well be a viable alternative to the present use of petroleum products in the brooding of poultry.

RESEARCH FACILITIES

To properly evaluate the potential for utilization of solar energy in poultry production units, careful evaluation of the mechanics involved in collection, storage, and delivery of heat to poultry houses must be completed. For these reasons, the Auburn Research Group designed and constructed an energy research facility for a long term study of energy in poultry production.

A totally enclosed house with six research rooms, 6.1 m wide by 11 m long was constructed (Brewer & Flood, 1978). Air exchange in each room is furnished by two, 2-speed fans capable of delivering a maximum of 3.5 m^3/s of air. Air inlets are along the south wall at ceiling level and are controlled by two-way baffles. The fans are controlled by off-on switches, thermostats, and percentage timers. Electricity is metered to each room separately. Within each room there are three metered circuits; fans, overhead lights and ceiling outlets for electric brooding. Each room also has metered LP gas and hot water (solar) heat.

The floors in all experimental rooms are dirt. This allows for variation of heat exchangers and brooders while studing the solar system.

An additional 6.1 m x 11 m room serves as control room for the solar system.

The solar collector system consists of a set of flat plate collectors manufactured by Revere Copper and Brass Company, Inc.

The absorber plates are of copper and the collectors are double glazed with glass. Net collector surface area is approximately 65 square meters. Storage is provided by three 3,785 liter steel tanks. Plumbing is arranged to permit operation as one, two, or three systems depending upon experiment objectives.

Hot water supply to the research pens is maintained at a constant temperature by a mixing valve which controls the amount of water recirculated and the amount drawn from storage. As many as three separate supply systems may be operated at one time. Typically, research pens will be paired so that each of the three systems will provide hot water to two pens. Water flow rate through the delivery system in each pen is controlled by a proportioning valve which operates on exit water temperature.

Temperature measurements in the solar system and environmental parameters within the broiler house are made with thermocouples. Waterflow measurements are made with turbine flow meters. A 192 channel data logging system provides continuous monitoring of these data and meteorological data. Two 20-channel event recorders monitor pump, fan, switch, and valve operation. Sub-metering of electricity permits separation of power consumption by lights, fans, brooding, etc. Ventilation air flow is also monitored by elapsed time meters on each fan.

Meteorological parameters effecting the operation and energy exchange of solar collectors used in this program are measured under the direction of the National Weather Service, Environmental Studies Service Center, located on the Auburn University Campus.

The meteorological parameters which are measured are: solar radiation available at the collectors and that incident on

a horizontal surface, air temperature, air speed and direction, dew point and background thermal radiation. The air temperature is measured at the height of the solar collectors and in a standard weather shelter in order to provide data regarding the collector environment and enable it to be related to climate measurements of the type universally collected. The solar radiation is measured with instruments that are sensitive to solar energy from any angle above the plane of the instrument and measurements allow comparison of the energy received in the plane of the collectors with energy received on a nearby horizontal surface, which is the normal climate neasurement. Wind is sensed at collector height only, as is dew point.

BROODING SYSTEMS

Four hot-water brooding systems and one ventilation air preheater have been tested. Tests have also been run using conventional LP gas brooders in order to get a comparison with current practice.

A concrete slab, 3 meters by 8.8 meters was centrally located in two of the research rooms. CPVC pipe was imbedded 5 cm below the slab surface on 33 cm centers. The slab covered approximately one-half of the floor area of each room. Wood shavings litter material was placed on the floor surrounding the slab but the slab was kept free of litter material. Manure was allowed to build up on the slab as birds grew. Performance of this system was generally satisfactory. In warm or hot weather manure becomes a problem. Little heat was required during this period; consequently, moisture in the manure was not evaporated. During winter months heat requirements were such that manure on the slab could be kept dry.

The remaining three brooding systems each made use of finned tube convectors located along one sidewall of the research rooms. A total of 18.3 linear meters of tubing was used per room. The first of these systems operated as a whole room brooding system. Tubes were mounted 30 cm and 45 cm above the floor. Room air was then heated by natural convection. In the second finned tube system, the tubes were both mounted 45 cm from the floor on 15 cm centers. A 120 cm wide hover was placed over the tubing 75 cm from the floor. A plastic curtain hung from the edge of the hover to within 6 cm of the floor. Heat transferred to air under the hover was by natural convection. Air space under the hover was maintained at the desired brooding temperature while room temperature was somewhat cooler. The third finned tube system was identical to the second with the exception that a means for forced air movement over the tubing was added. A section of 13 cm diameter corrugated plastic drain pipe was placed over the tubing. Fans were placed in each end of the pipe. Holes in the bottom of the pipe directed air over the finned tubing.

An inexpensive ventilation air preheater was added to four of the rooms. The vertical wall air heaters were constructed of 5 cm x 5 cm framing material with a single glazing of kal wall plastic. Thirty pound building felt was stapled to the back of framing members to act as the absorber surface. Air enters the top of the collector, passes down between the glazing and absorber surface and then passes up behind the absorber surface to the ventilation air slot inlet. Since there is no storage associated with this system, it is effective only when energy is available.

RESULTS

Eleven trials were run during the period 1977-1979. Evaluation of brooding system performance showed that all systems satisfactorily maintained the desired thermal environment.

The concrete slab brooding system supplied 90-100% of the brooding energy from solar during late winter, spring, summer and fall trials. Solar supplied 48 to 76% of the energy during January - February trials. November - December trials ranged from 26 to 34% from solar. This points out a problem encountered in the Southeastern United States. During November and December, extended periods of cloudy weather are quite common. When cloudy weather coincides with the start of a grow-out period, solar will not supply a large percentage of the required brooding energy because of the pattern of energy needs. While the slab system satisfactorily supplied energy needs during warm months, a serious management problem developed in that heating requirements were so low that manure which accumulated on the slab was not dried out. A water temperature of 50 C was required for this system.

Only two trials were run using the finned tubes without a hover. In a November - December trial 37% of the brooding energy was from solar while in a February - March trial 66% was from solar. This type of system did not seem to be a viable candidate for the open type housing used in the Southeast since the entire house was being warmed rather than the floor area where birds were located.

Hovers, 1.2 meter wide, were added to the finned tube systems in November 1977. November and January trials were both conducted during periods of relatively cloudy weather. Solar supplied 41 and 49% of the brooding energy, respectively. During other periods

solar was able to supply 90 to 100% of the energy needs. In addition to an increase in the percentage of brooding energy supplied by solar, the addition of the hover resulted in a decrease in required water temperature from 60 C to 45 C. Addition of forced air movement over the finned tube did not improve the portion of energy requirements supplied by solar but did result in a futher decrease in the required water temperature to 40 C. The reduction in water temperature necessary for system operation effectively increases the energy storage capacity of the water tanks. It also should improve collector efficiency in that storage temperatures may be maintained at a lower level.

The ventilation air pre-heaters were added to the system in 1978. Cost was about ten dollars per square meter. The addition of about 20 square meters of pre-heater to each room reduced auxiliary heating requirements 41% for the four trials run. Roof overhang is such that pre-heaters are effective from November through March.

Collector area and storage volume are major design parameters in any installation. However, several other parameters may have an important role in the conversion of solar insolation to usable heat. Such parameters are: collector efficiency, piping and storage losses, minimum usable storage temperature, ambient air and thermal mass of the collection system. Solar parameters such as instantaneous intensity, duration, and time distribution interact with the system parameters and influence the percentage of available energy which is converted to collected energy. Collected energy will always be less than that available. Figures 5 and 6 show the daily totals for collected energy, available energy and

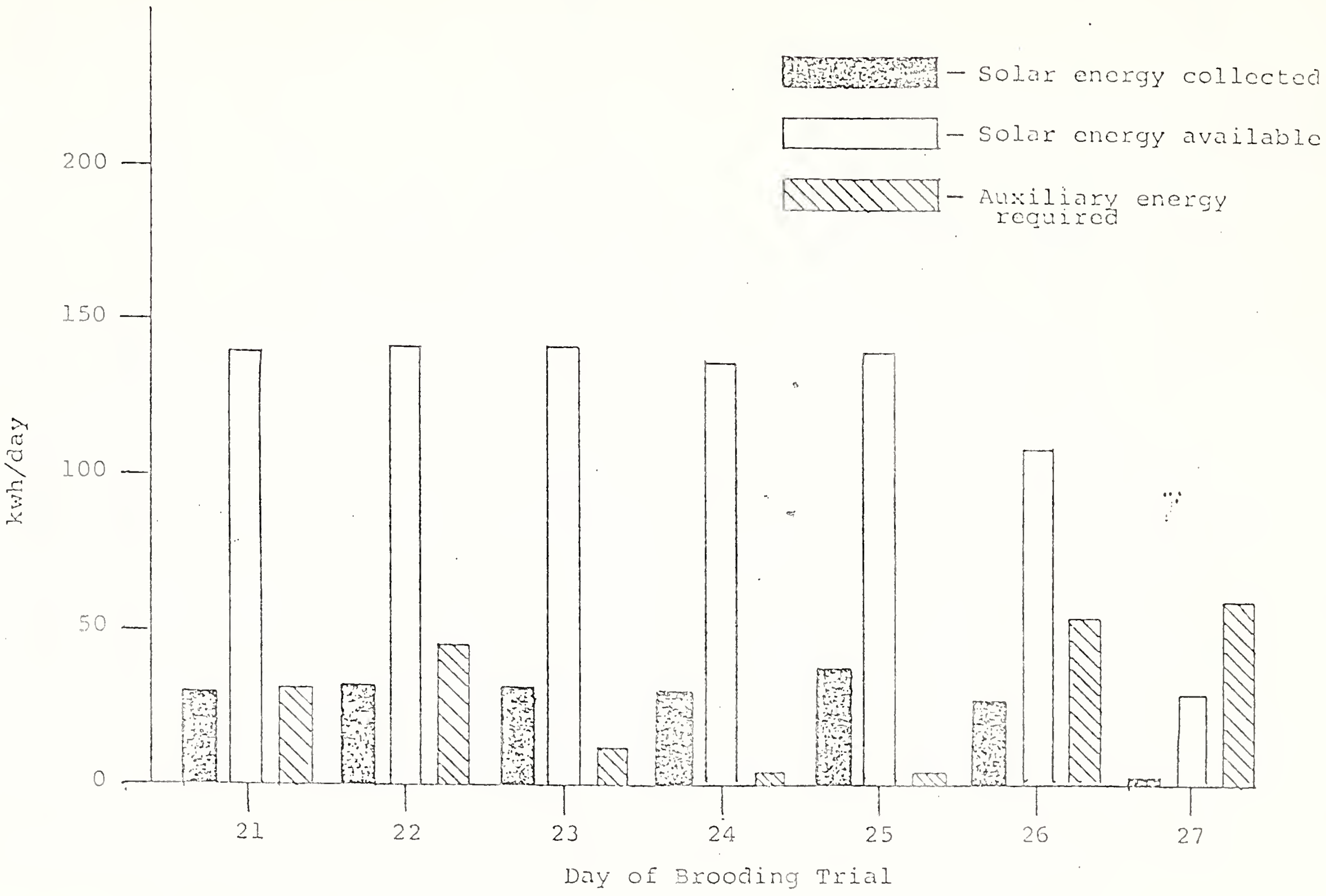

Fig. 5. Typical energy patterns in solar system

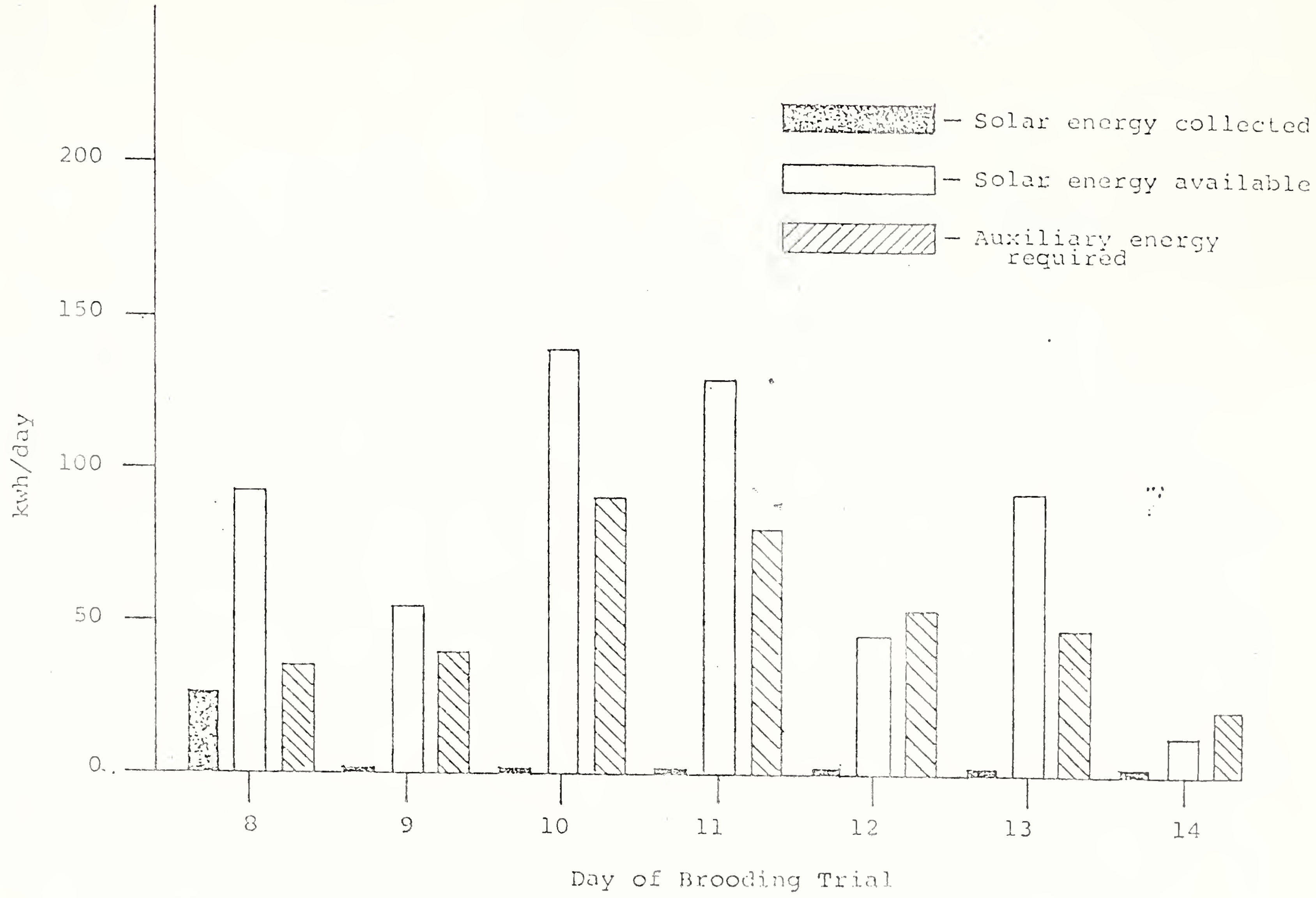

Fig. 6. Typical energy patterns in solar system

auxiliary heat required. Figure 5 covers a typical week when the sky was relatively clear and the collected heat represented a sizable portion of the daily requirements. Figure 6 shows the same type data for a week in which the available insolation was substantial although below the values for the previous week. This second week was characterized by hazy days, intermittent clouds and days of almost total cloud cover. The system thermal lay resulted in essentially zero energy collected for the week. The Southeastern United States during fall and winter is characterized by extending periods of such weather, making solar energy predictions uncertain.

CONCLUSIONS

The results of this research program show that it is technically feasible to use solar heated water to provide a major portion of the brooding heat needed by broiler chickens. System efficiency is improved by using hover type brooding systems rather than heating the entire growing chamber. System efficiency is also improved by lowering the minimum required water temperature. Inexpensive ventilation air pre-heaters may make a significant contribution toward meeting heat needs. This is particularly true as birds age and ventilation requirements increase. The time distribution of energy needs associated with current brooding practices make it difficult to design solar heated systems which do not have significant excess capacity during the last half of a grow-out period if they are to meet a major portion of needs during the early part of a production cycle. Further reserach is needed on heating system and broiler house design as well as poultry management

as it affects brooding in order to develop a solar heated broiler brooding system which can be effectively utilized all months of the year. In addition, development of multiple uses of the solar heating system which are compatible with broiler production, can enhance the utility of its application.

REFERENCES

Brewer, R. N. and J. R. Dunn, 1975. Potential for conversion and utilization of solar energy in poultry production. Final Report NSF/RANN/SE/PTP74-23987/PR/74/4.

Brewer, R. N. and C. A. Flood, Jr., 1978. Solar heated solar house. Alabama Expt. Sta. Leaflet No. 96, July.

Brewer, R. N., M. White, C. A. Flood, Jr., J. L. Koon and G. R. McDaniel, 1978. Fuel use in poultry production. Poultry Sci. 57(2):363-369.

Flood, C. A., Jr., J. L. Koon and R. N. Brewer, 1979. Solar heating of poultry houses. 1. An analysis of energy use for brooding broiler chickens. Poultry Sci. 58(@):314-318.